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Executive Summary

The **Fiber Reference Image Library** (**FRIL**) https://fril.osu.edu/, a database of micrographs of textile fibers acquired through the use of multiple microscopic techniques, was created with NCPTT support. At present, the database contains 145 collections with 1404 individual files, and requires 23,339 MB of storage space. Each file contains a high resolution image with text fields that delineate image location and size, image collection information, microscopy technique and details of the features presented in the image. Micrographs are shown of single fibers and fiber groups examined using brightfield, darkfield, polarized light, and differential interference contrast techniques; the sequences of images provides information complementary to the others.

The database includes specific pages. Items in the **Glossary** document include example images which are linked to their source collections. The **Browse Collections** page provides an organized outline and links for ease of use of the reader. The **Resources** page provides literature for further study. The **Search** function is a Google type word search. The **How to Use the Fiber Reference Image Library** page provides a detailed explanation of the structure of the collections and how the images were collected. The **Research** page provides citations of research reports that are related to the use of FRIL. The **Outreach** page provides examples of the use of FRIL in educational and service perspectives.

The first phase of website construction, supported by the NCPTT grant, primarily focused on construction of the website template and inclusion of images of fibers from the **Comparative Plant Fiber Collection**, a collection of plant fibers typical of those used by prehistoric native Americans in eastern North America. Since the fibers were processed from the plant stems in different ways, the images provide evidence for the cellular structures that remain attached to phloem fiber cells with different types of processing and aid in fiber identification. This will be particularly useful for those who study fiber perishables.

The site also incorporates images of selected animal and man-made fibers. Images of fibers from selected 19th and 20th century garments from Ohio State University's **Historic Costume & Textiles Collection** (HCTC) are included and these are linked to images and information about the garments from which they came, housed under the HCTC website (https://mediamanager.osu.edu/). Links from FRIL to the website of the Ohio State University's Historic Costume & Textiles Collection provide a template for further development as FRIL is expanded beyond plant fibers to all fiber genera.

Introduction

Fiber perishables are a valuable archaeological artifact class from which many inferences can be made concerning the technology of their production as well as the social psychology of their use. Objects such as textiles, basketry, cordage, or sandals are made through various means of combining yarns, such as interlacing, twining, weaving, or knitting. Yarns are generally made from individual fibers that are bundled together. Fibers are the fundamental building blocks of these objects. A fiber is "a generic term for any one of the various types of matter that form the basic elements of a textile and that is characterized by having a length at least 100 times its diameter" (American Society Testing and Materials 2006). "Although unevenly preserved in the archaeological record, fiber-perishable artifacts have the potential to significantly increase our understanding of prehistoric technologies and stylistic behavior." (Society for American Archaeology 2008) Through the study of fiber perishables, we can learn which fibers were employed in their manufacture, how these fibers were processed from raw materials, how they were spun into yarns, how the yarns were combined to produce the object, and how the material was colored or further decorated. We can infer the cost in time and effort in product manufacture, thereby demonstrating the complexity of craft production within a social group. Understanding the stylistic features of the objects leads to socio-psychological inferences such as ethnic identity and status. Whether commodity goods or luxury items, produced for local use or the ruling class, fiber perishable products provide evidence of the history of the period of their manufacture and use and evidence for their social and political significance as items of bestowal and exchange, tributes dress and adornment, or emblems of investiture and rulership (Schneider and Weiner 1989). Finally, whether the fiber perishable object is preserved or altered, desiccated or waterlogged, mineralized or charred, a conservator is better able to determine appropriate preservation techniques by thorough understanding of the chemical and physical characteristics of the fiber components of the object. Thus a key to many areas of fiber perishables research is the identification and characterization of the fibers from which the object is made.

The goal of the project undertaken with NCPTT support was the creation of a web-accessible database of images and text of the fiber materials held in the Comparative Plant Fiber Collection (CPFC). The CPFC contains representative plant specimens and the fibers from plants typical of those used by prehistoric native American groups in eastern North America. Through the creation of this website it was envisioned that the global research community of ethnobotanists, archaeologists, textile scientists and all those interested in fiber perishables and material culture would have access to multiple images of the fiber examples from thirty-four different plant genera and species from two regions in the eastern US represented in the collection. Because each of these fiber groups were subjected to four different types of processing methods, the database of images will serve not only as an aid to fiber identification but also will be useful in discerning the techniques employed in fiber processing and in characterizing the extent and types of degradation incurred by the fiber perishable object.

The database also serves as a template for future growth of the Fiber Reference Image Library and is linked to another growing database of images and text from the Ohio State University Historic Costume & Textiles Collection.

Methods and materials

At the start of the project, the site URL of fril.osu.edu (hereinafter labeled FRIL) was reserved. (Note: the original proposal indicated that the website would be called cpfc.osu.edu, but when working with the materials it was decided that we should use the title by which the entirety of the fiber genera used in textiles could be encompassed. This was done to assure name recognition for the Fiber Reference Image Library from its inception). Through a number of meetings with OSU's Media Manager personnel, Jakes was trained to use the Media Manager platform, thus she was able to develop a site with text fields, collections and subcollections, and links from one document or image to another. She devised the data entry list, programmed the fields for data entry, devised the map of the entire site, and wrote the text for all pages with informative text.

Concomitantly, Crawford examined and photomicrographed fibers from the Comparative Plant Fiber Collection which includes over 1000 fibers on slides mounted with Permount, a medium with a Refractive Index of 1.515. These formed the basis of the fiber subjects that were examined microscopically and photomicrographed digitally for this project. In some cases, these slides proved to be too thick to image individual fibers clearly or had some other problem, so new slides were prepared using the processed fibers from the CPFC and mounting with Meltmount (RI 1.539). This mounting agent is convenient to prepare and provides good contrast for textile fibers. In an effort to go beyond the scope of the proposed database, additional commercial fibers were mounted and examined as well as fibers obtained from 5 historic garments from the Ohio State University's Historic Costume & Textiles Collection.

Each of the microscope slides were examined at both 200X and 400X using brightfield, darkfield, polarized light and differential interference contrast techniques and employing a Zeiss Axioplan Research Microscope. Digital images were collected using a Zeiss HRC Axiocam camera. After performing white and black balancing to calibrate the camera, images were collected in Zeiss format with a resolution of 2776 x 2080 pixels scanned color. All images were labeled with a scale bar and saved in TIFF format with identifying information including date of image capture. If further information is needed the Zeiss software stores a history of the image preparation steps and size.

For the bast (plant stem) fibers, effort was made to isolate a single fiber, to discern distinguishing characteristics. To accomplish the Herzog test, the First Order Red plate was added to the optical train along with crossed polars to reveal evidence of fibril spiral direction, i.e. S or Z. In addition, images were taken of fiber bundles and associated materials, thereby displaying the structures that remain adjacent to the fibers and that might provide additional identifying information.

Each image was uploaded into the Media Manager database housed under FRIL. For each image, information concerning image capture, accession numbers and other appropriate descriptive fields represented on the image were selected. All entered data was saved on the Media Manager server, which is backed up weekly.

When examining man-made fibers, the fiber was oriented at the position of maximum brightness under crossed polars and the First Order Red Plate was added to determine the sign of elongation.

To improve images for objects with multiple layers of interest and for which the depth of field is insufficient to allow viewing of objects in focus over the entire image field, multiple images were taken at different focal planes, and combined using the shareware program, Combine Z (Piper 2008).

The database structure was developed using the university's Media Manager software. Fields that were included in each record of the database were determined by accumulation of plant fiber information from the botanical and textile fiber literature, including the reports published on the CPFC (Jakes 2003, 2000, 1996; Jakes et al 1993, 1994). Data entry fields included plant and fiber identification information, image capture information and morphological features displayed in the imaged fiber. Drop down boxes were developed for item fields that required a selection from a number of choices. As manufactured and animal fibers were added, appropriate fields for these categories were added based on literature on fiber identification and characterization through microscopy (McCrone 1980; Petraco & Kubic 2004)

A graphic designer/ web programmer was employed to develop the front page design of the site and program some page structures for ease of use. A Google Analytics code was included in the front page for collection of statistics on site visits upon release of the site to the public.

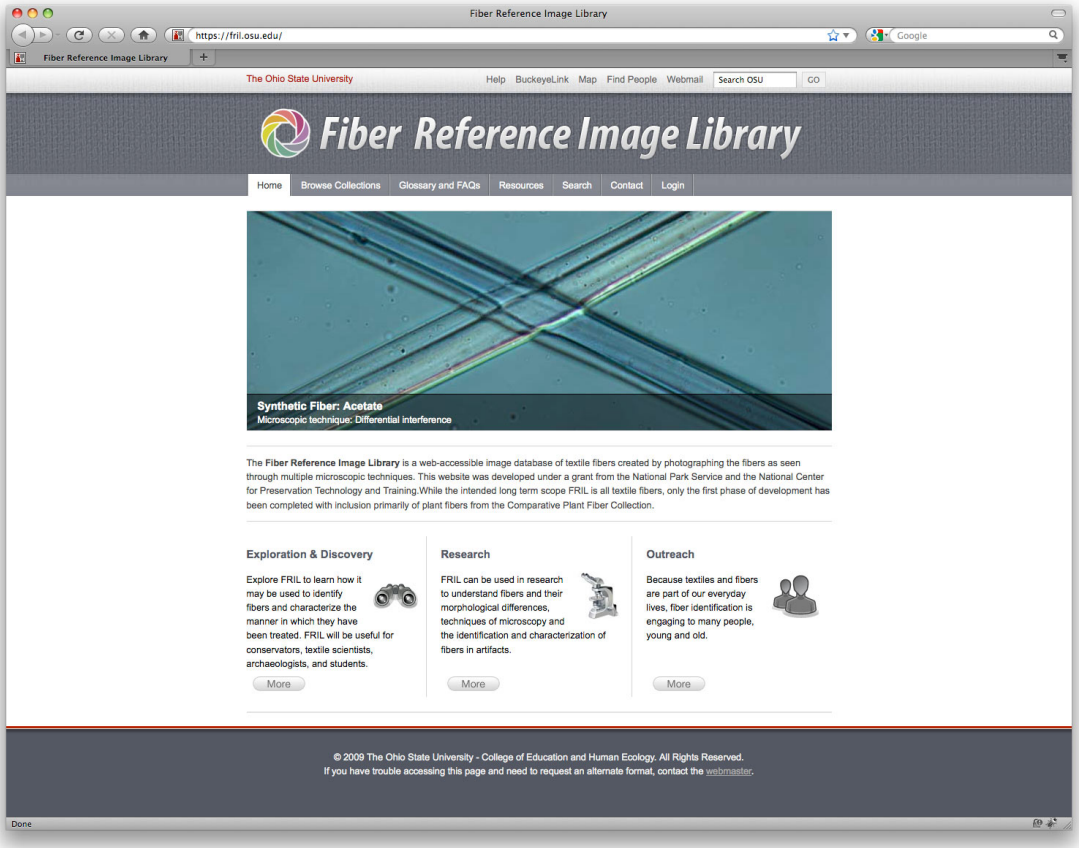
The database was reviewed by seven individuals with differing interests and research pursuits related to fibers and fiber perishables. The reviewers were asked to test the database, challenge its searchability, as well as its comprehensiveness. They reviewed the entire site including all of the page links e.g. to the terminology. Every comment made by a reviewer was addressed. Comments included such things as changing some page titles (change "Terminology" to "Glossary"; change "Exploration" to "How to Use FRIL"). Search issues that arose during the review were addressed. The only suggestion that was not possible was the creation of links in the resource section to journal article pdfs. Obtaining copyright approvals for each of these was deemed unfeasible at this time. One goal of the investigator is

the addition of the abstracts for the journal articles she published that are listed under "Research". This might guide the viewer toward further information as the reviewer desired.

Although additions continue to be made to the database, it was released to the public on April 1, 2010.

Results and Discussion

The front page of FRIL (Figure 1) displays a rotating slideshow of example fibers and labels, surrounded by attractive wallpaper. A neutral gray background with some texture was selected so as to not interfere in color assessment of the fibers, particularly important for those that display significant birefringence. The knot logo of multiple colors was designed to give FRIL its own "brand", to be recognizable when the page is viewed.



Tabs across the top include choices of **Home**, **Browse Collections**, **Glossary and Frequently asked Questions**, **Resources**, **Search**, **Contac**t. The lower half of the page presents tabs titled **How to Use FRIL**, **Research** and **Outreach**. Each of these link to other pages of content that provide further detail on each of these topics.

The **Browse Collections** page clearly separates the topics of Animal Fibers, Plant Fibers and Manufactured Fibers. Clicking on the topics underneath any of these brings the viewer to the collection, with further subcollections that can be found within that collection. The viewer then sees an individual image with text below it organized to explain the image. Because of the high resolution of the images, the zoom feature available for each image allows increasing close views of features of interest. All images are watermarked to provide security; if one is downloaded the watermark is carried with the image. For those who want to download a high quality image, contact can be made to the manager of FRIL.

The **Glossary and Frequently asked Questions** page is subdivided so that the viewer can readily locate the subject are of interest, Plant Fiber Morphology, Comparative Plant Fiber Collection,

Animal Fiber Morphology, Manufactured Fiber Morphology and Microscopy and Image Capture Techniques. The **Glossary** document provides text and sample images of fiber microscopic features such as lumen types, fiber bulging, fibrillation, crystals, parenchyma cells, cambium residues, dislocations, kinks, and cracks. It also provides explanation of the Herzog technique among other techniques of microscopy. Within each of these definitions, where appropriate, an image is provided which displays the feature being defined. Clicking on the image takes the viewer to that fiber's collection so that images may be compared. An example is inserted below.

FAQ: dislocations

Disruptions in sclerenchyma cells that appear ubiquitously in plant stem fibers. Disruptions of slip planes, perhaps associated with compression failure. (Catling and Grayson1998)

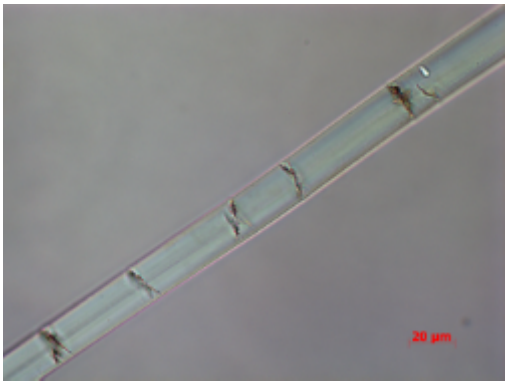


Figure 2. Example of data in the Glossary document. Definition and image example of dislocations.

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The **Resources** page includes many references that can be used to find further information about fibers, as well as of the fiber identification or microscopy techniques. The **Search** function available through Media Manager is a Google type search; entry of a word will yield all collections that contain that word in their data fields. **Contact** information is provided for those who need additional help.

The FRIL site contains 144 collections and over 1404 individual images. The fiber images of a single fiber specimen can be seen in a series within its collection, followed by images of additional key features representative of the fibers and the associated materials observed. The sets of images reveal features not visible with the use of one technique alone. Thus, for example, multiple images of a single fiber are shown below, each provides information complementary to the others.

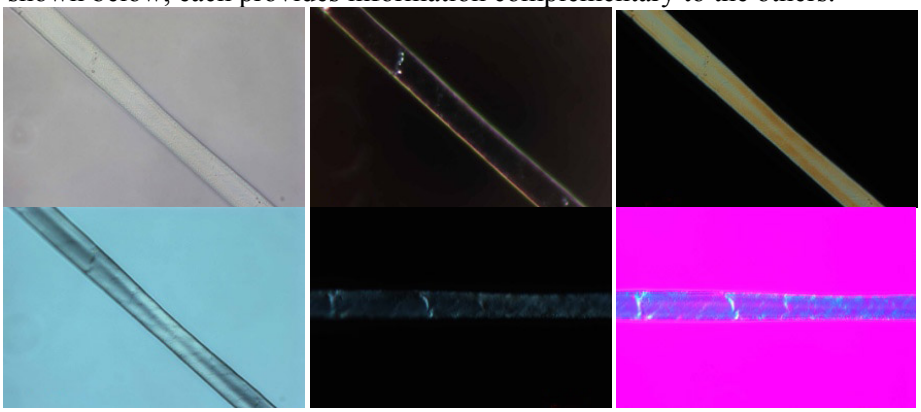

Figure 3. Example of brightfield, darkfield, polarized light, differential interference contrast, polarized light at extinction and polarized light with First Order Red plate with exaggerated color.

The FRIL database includes the following plant fiber collections from the Comparative Plant Fiber Collection

1. Dunal paw paw, GA and OH
2. Spreading dogbane, GA and OH
3. Indian hemp, GA and OH
4. Intermediate dogbane, OH
5. Blue dogbane, OH
6. Butterfly weed, GA and OH
7. Swamp milkweed, OH
8. Common milkweed, OH
9. White milkweed, OH
10. Poke milkweed, OH
11. Eastern red cedar, OH
12. Giant cane, OH
13. Small cane, OH
14. Black walnut, OH
15. Red mulberry, |GA and OH
16. Eastern cottonwood, OH
17. Black willow, GA and OH
18. Moosewood, OH
19. Narrow-leaved cattail, GA and OH
20. American basswood, GA and OH
21. Slippery elm, OH
22. Rattlesnake master, OH
23. Stinging nettle, GA and OH
24. Wood nettle, OH
25. False nettle, OH

Each of these 25 fiber groups is subdivided into treatment groups (subcollections in the database) based on the method used in separating the fiber from the remainder of the plant stem. Differences seen in microscopic structure between fibers from the same plant genus and species but processed in different ways can be seen and compared using the database.

Within each record in addition to the image, text fields include

a. Those associated with image location within the database
    a. Image location on Media Manager
b. Descriptive information concerning the fibrous material from which this individual fiber came
    a. Accession number
    b. Title or label for the fiber
    c. Fiber source, plant or animal or manufactured
    d. Plant processing category
c. Information concerning image capture
    a. Date
    b. Microscopist
    c. Microscope and camera identification
    d. Mounting agent and refractive index
    e. Microscopic technique employed

d. Information concerning fiber morphology and other details of the image
    a. Presence of Lumen
    b. Lumen filling
    c. Presence of swelling or bulging
    d. Presence of fibrillation
    e. Fiber size – relative. (since scale bars are present on all images, the viewer also knows the exact fiber diameter of any viewed fiber)
    f. Presence of dislocations
    g. Presence of transverse markings
    h. Presence of surface folds
    i. Presence of Longitudinal markings
    j. Presence of Kinks
    k. Presence of Cracks
    l. Presence of Crystals, with a drop down of 6 different categories
    m. Presence of cambium
    n. Presence of parenchyma cells
    o. Results of the Herzog test, S or Z fibril spiral

For images of animal hair fibers, categories for data entry also include presence or absence of cuticular scales. In the future with larger collections of animal fibers, subsets of scale shape will be added. For images of manufactured fibers, categories to be entered include longitudinal morphology, presence of delusterants, and determination of the sign of elongation.

Beyond the inclusion of all of the examples of the Comparative Plant Fiber Collection, additional fiber genera included in the database are: cotton, flax, jute, hemp, sheep's wool, silk, acetate, acrylic, nylon and polyester. Within five of these collections are included subcollections of images of fibers removed from historic items of dress from the Ohio State University Historic Costume & Textiles collection. The pages with these subcollections also provide links that take the viewer to images of the particular garment at the Historic Costume & Textiles Collection website. Here the viewer may see multiple images of the costume, presented on mannequins and photographed as the mannequin is turned 360 degrees. In addition to zoom capability allowed in the high resolution images, photographs of close ups of garment features are included as well.

FRIL allows users to view and download watermarked images for their use in fiber identification and characterization, although at somewhat less image quality as those displayed. An opportunity to obtain high resolution is offered through contact with manager of the FRIL site, K. Jakes.

Upon completion of the proposed work encompassed in the NCPTT proposal, the FRIL database was released to the public. Announcements of the availability of the FRIL database were sent to

a. the Fiber Perishables Interest Group members listserv, listed May 2010;
b. the newsletter of the Society for American Archaeology, published May 2010, p.58;
c. the newsletter of the American Institute for Conservation;
d. the e-newsletter of the Textile Specialty Group, listed May 2010 ;
e. the Ohio Archaeological Council newsletter; and
f. Education Week, a professional news magazine for teachers.

Announcements were also sent to all of the reviewers and to individuals who contacted Jakes over the period of the database construction work expressing interest in having access to the database.

Upon completion of the proposed work and release of the FRIL site to the public, Ohio State University's Media Manager program posted a link to FRIL on its website mediamanger.osu.edu. The link includes a screen shot of the FRIL front page and a description. This will add to the traffic generated on campus, since many use Media Manager as a site for images for courses and research.

Two presentations were given at the Historic Costume & Textiles Collection Symposium on May 22, 2010. One presentation focused on using FRIL when determining fiber content in prehistoric native American textiles, the other focused on using FRIL for identification of the fiber content of a 1980s

couture garment. The presentations also addressed the use of the database as a tool for enhancing instruction for middle school aged children; it is envisioned that with continued development the website will include components easily adaptable by middle school educators for use in classroom exercises for topics in science and technology and social sciences.

Jakes will give an invited presentation on the use of FRIL at the American Institute for Conservation meeting to be held in Pittsburgh in May 2011.

Jakes is collaborating with the curator of the Historic Costume & Textiles Collection in the preparation of a proposal to the National Endowment for the Humanities Preservation and Access Program for the next level of database development. The proposal will be submitted in July 2010 for funding beginning May 2011. Crawford will continue as microscopist on the project.

An article describing the use of FRIL to enhance middle school education is in preparation. An article showing the linkages between the identification of fibers from archaeological textiles and the FRIL database is in preparation.

Conclusions

The Comparative Plant Fiber Collection contains representative plant specimens and the fibers from plants typical of those used by prehistoric native American groups in eastern North America. The fiber collection was generated to include examples of fibers that result from different processing techniques and the goal of that collection was to serve as comparative materials aiding in the identification and characterization of fibers found in prehistoric textiles. Since its inception, researchers have inquired to have access to the CPFC, and to have help in fiber identification in artifacts through comparison to the database. No comparable database of any kind exists, whether in book or digital form.

While McCrone's Particle Atlas (1980) provides a key for plant fiber identification, and Catling and Grayson (1982) include some micrographs of plant fibers, both are focused on commercial plant fibers and do not consider the vast array of materials used prehistorically. Florian et al (1990) addresses conservation of plant-based artifacts, and includes some micrographs but does not include all fiber plants. By comparison to the multiple facets of the CPFC, an analyst can classify fibers. For example, in addition to dislocations typical of bast fibers, Indian hemp and other dogbanes in the *Apocynum* genus display characteristic surface folds. Fibers from woody plant stems like black walnut and basswood can be classified based on the presence of calcium oxalate cellular inclusions of particular shapes. Extent of processing can be inferred from such attributes as the presence of parenchyma cells and cambium on the surface of a fiber bundle, a feature indicative that the fibers had been extracted without having undergone a retting process (Jakes et al 1993, 1994; Jakes 1996).

Funds were sought from NCPTT to establish a database that would be accessible to researchers as they examine fibers from prehistoric and historic plant based textiles, particularly those from eastern North America. This goal was achieved but development of the database went beyond the scope of the NCPTT proposal. The FRIL database that has been initiated forms the "proof of concept" template for a much larger database. FRIL continues to grow, as we add images of fibers from historic garments from the HCTC and add more comparative plant, animal, and manufactured fibers. With this proof of concept in place, Jakes is preparing a proposal for expansion of the database to be submitted to National Endowment for the Humanities in July 2010.

But FRIL is more than a template for future proposals, it serves as the only digital database of plant fiber micrographs. It has already been used by multiple researchers for comparative information including those who examine prehistoric fiber perishables and those who conserve paper. It has spurred others to think about accumulating comparative materials for identification in other applications. Since its release on April 1, the FRIL site has been visited by 1808 individuals and 14, 278 page views. More than half the visits were direct traffic, i.e., people intentionally entering the FRIL site by entering that web address, and another 34% of the traffic directed by a weblink, a likely result of the posting of the site on other websites such as the Fiber Perishables listserv.

Although many fabrics and other fibrous artifacts are found in North American archaeological sites, only the most well preserved, such as those from the dry Southwest, garner significant attention

while the smaller, less well preserved fragments have received less attention. Yet all of these fiber perishables are valuable artifacts that embody critical information about the fibers used, the extent of processing employed in extracting them from plant sources, dyes and pigments used in their coloration, the means employed in combining the fibers into yarns, and their current chemical and physical condition. Many inferences can be made from study of fibers such as time and effort costs in manufacture, thereby demonstrating the complexity of craft production within a social group, and the environment of the archaeological context, thereby allowing a conservator to knowledgably prescribe preservation treatments. The achievement of development of a digital database of plant fiber images and text addresses a national need as it develops the foundation for comparison for identification and preservation of objects in the valuable fiber perishable artifact class. The database at Ohio State will grow, and provide further links to images of historic objects in addition to micrographs of sampled fibers, thus further expanding the usefulness of the database to conservators and curators of textile objects, textile scientists and students.

Acknowledgements
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Presentations

Jakes, K. A. "Prehistoric People's use of Plants for Fibers and Dyes", Historic Costume & Textiles Collection Spring Symposium, May 22, 2010, Columbus OH.

Crawford, L. C. and Jakes, K. A. "Clothes and Kids: Seeing Science and Technology Through the Study of Couture Garments", Historic Costume & Textiles Collection Spring Symposium, May 22, 2010, Columbus OH.